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Wakitani

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(54) **ELECTRIC VEHICLE**

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(52) **U.S. Cl.** **318/55**; 318/34; 318/59
(58) **Field of Search** 318/55, 34, 59; 150/65.1

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(74) *Attorney, Agent, or Firm*—Adams & Wilks

(57) **ABSTRACT**

An electric vehicle driven by electric motors is provided. The vehicle is switched between forward travel, neutral and reverse travel by a directional speed lever which allows adjustment of the vehicle speed. When the directional speed lever passes through a neutral region at a high speed during forward travel of the vehicle, the vehicle is controlled to shift to normal reverse operation after a lapse of a predetermined period of time since the rotational speed of the electric motors becomes zero, thereby to avoid application of a heavy load to drive circuits for the electric motors.

1 Claim, 13 Drawing Sheets

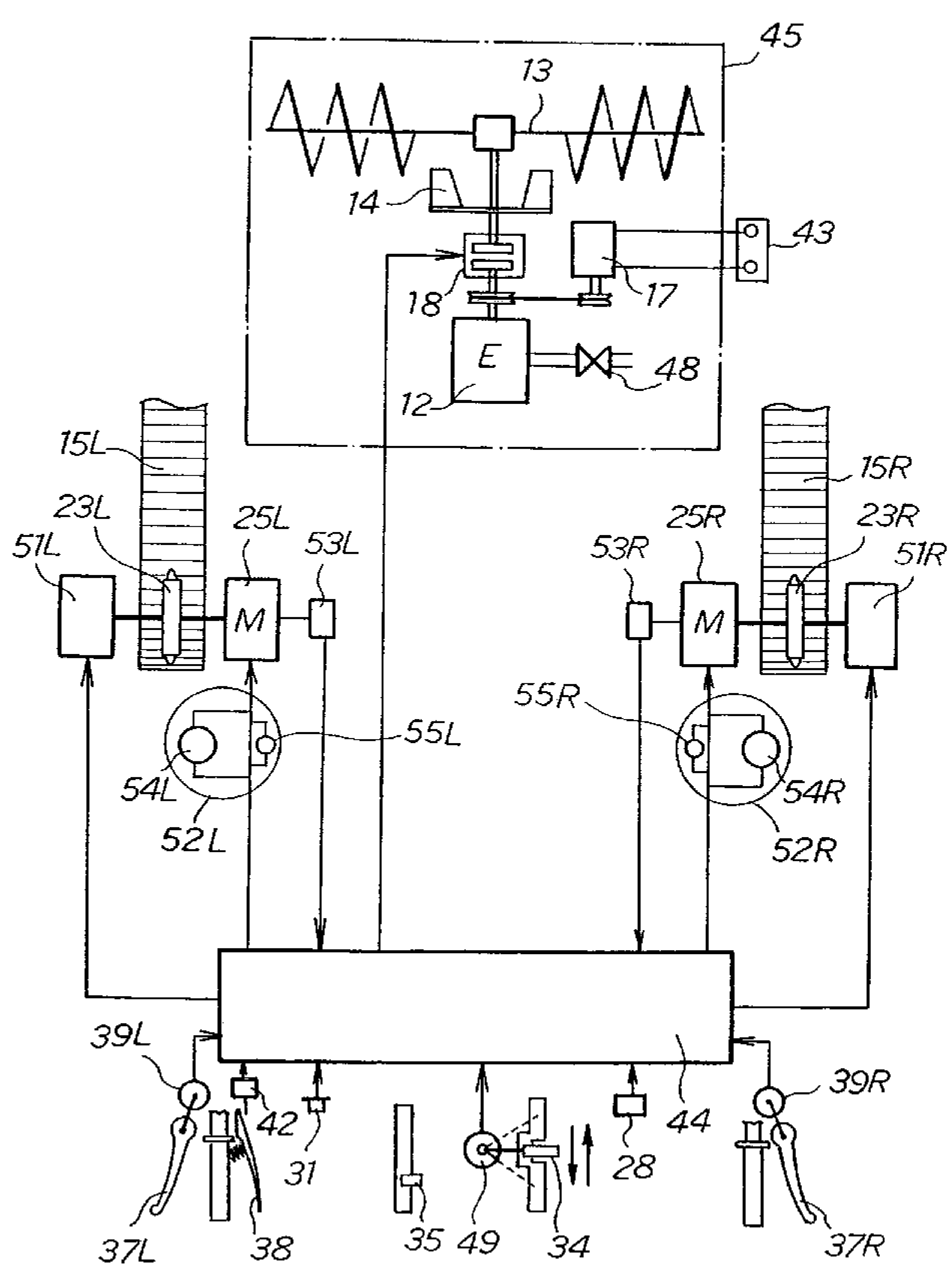


FIG. 1

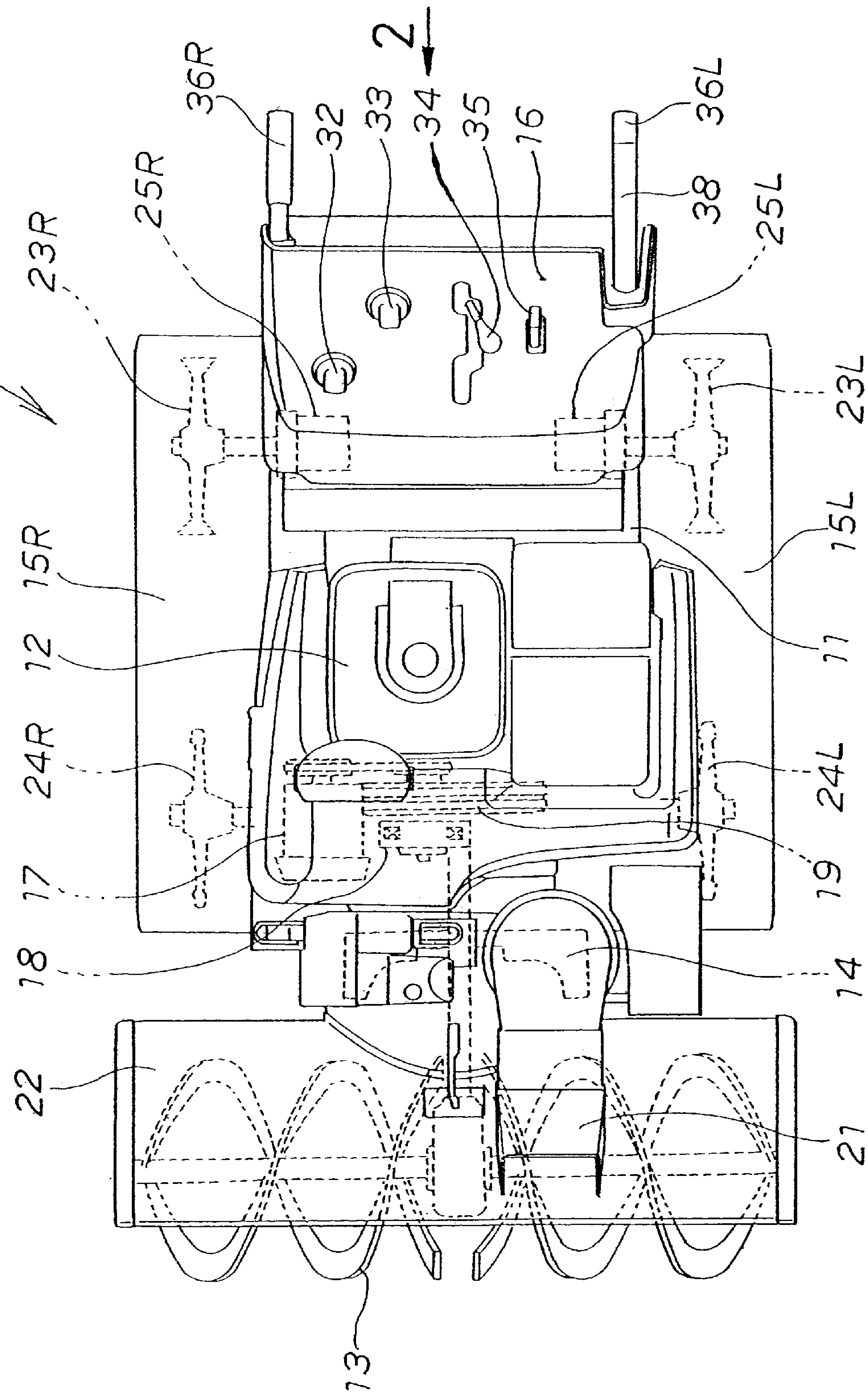

2
10
36R
32
33
34
35
16
36L
38
25R
25L
23R
23L
15R
15L
12
11
24R
24L
17
19
18
14
22
21
13

FIG.2

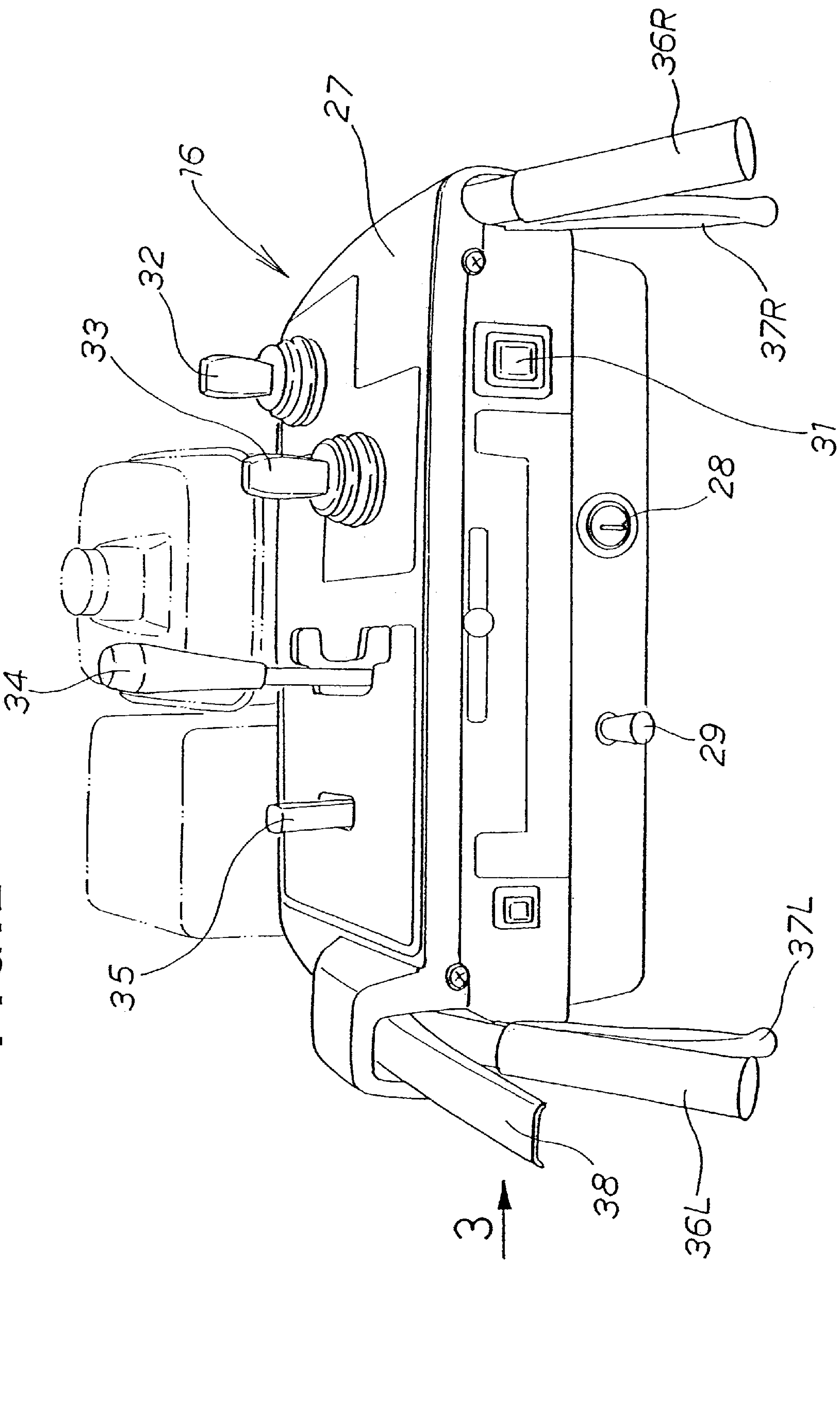


FIG. 3

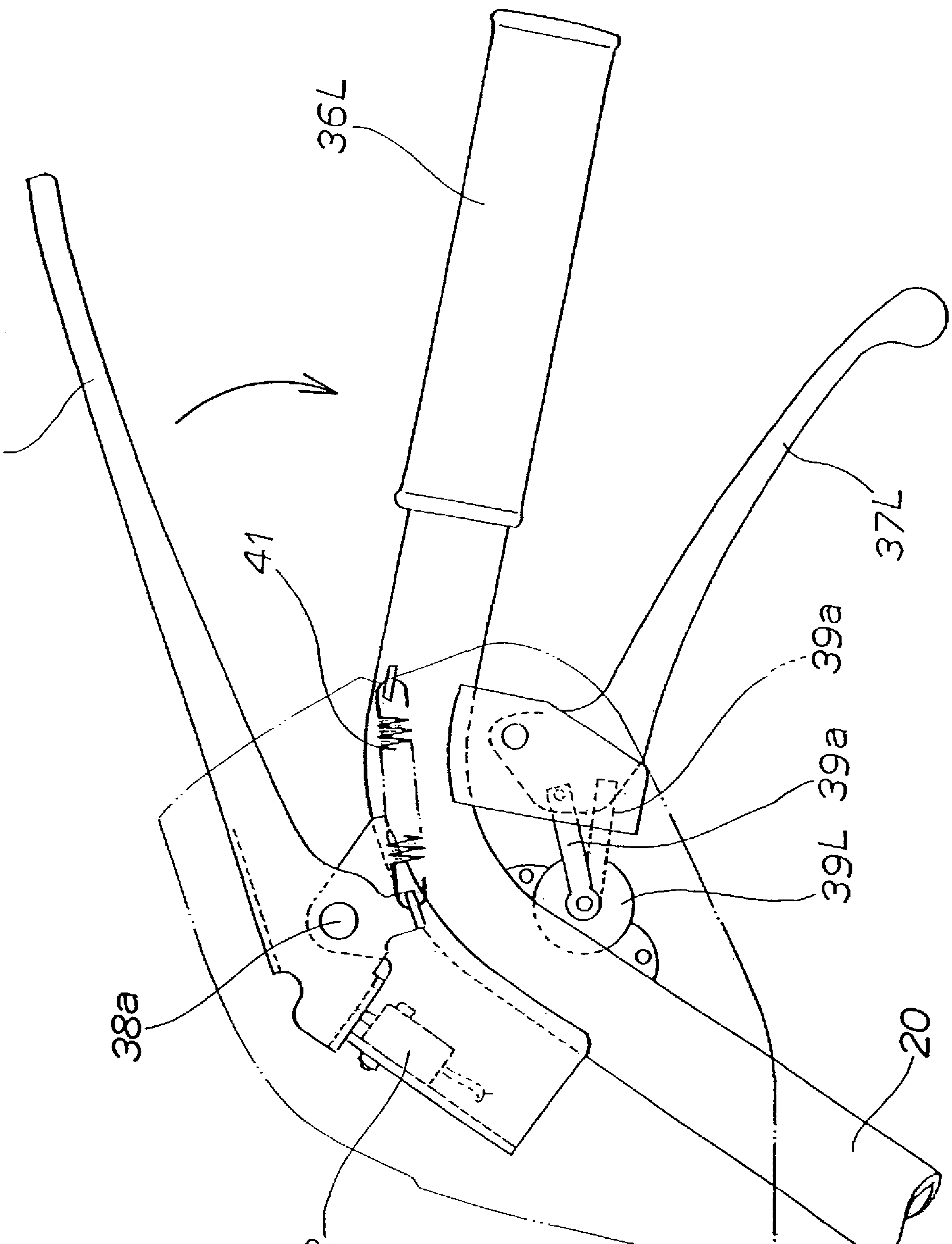
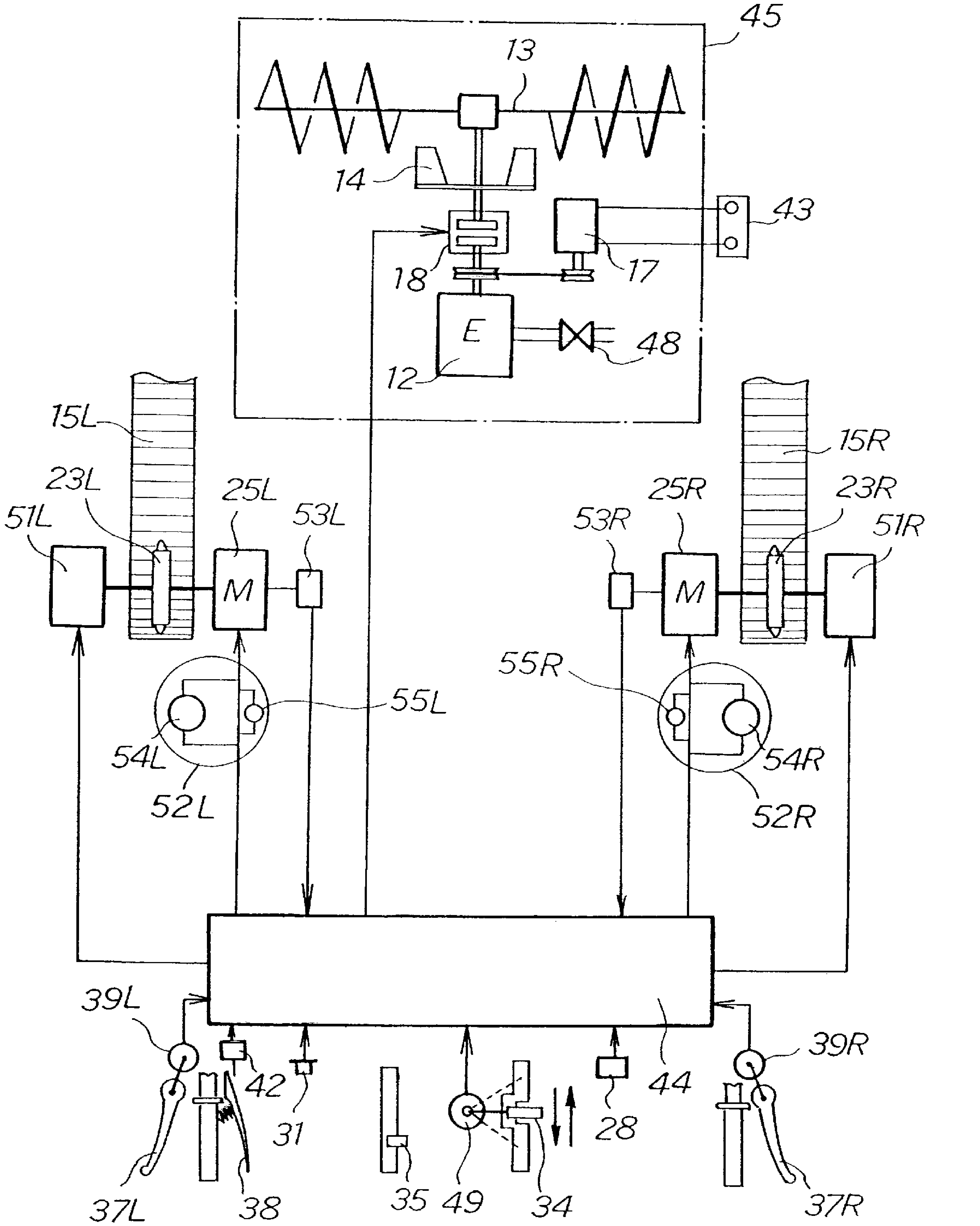
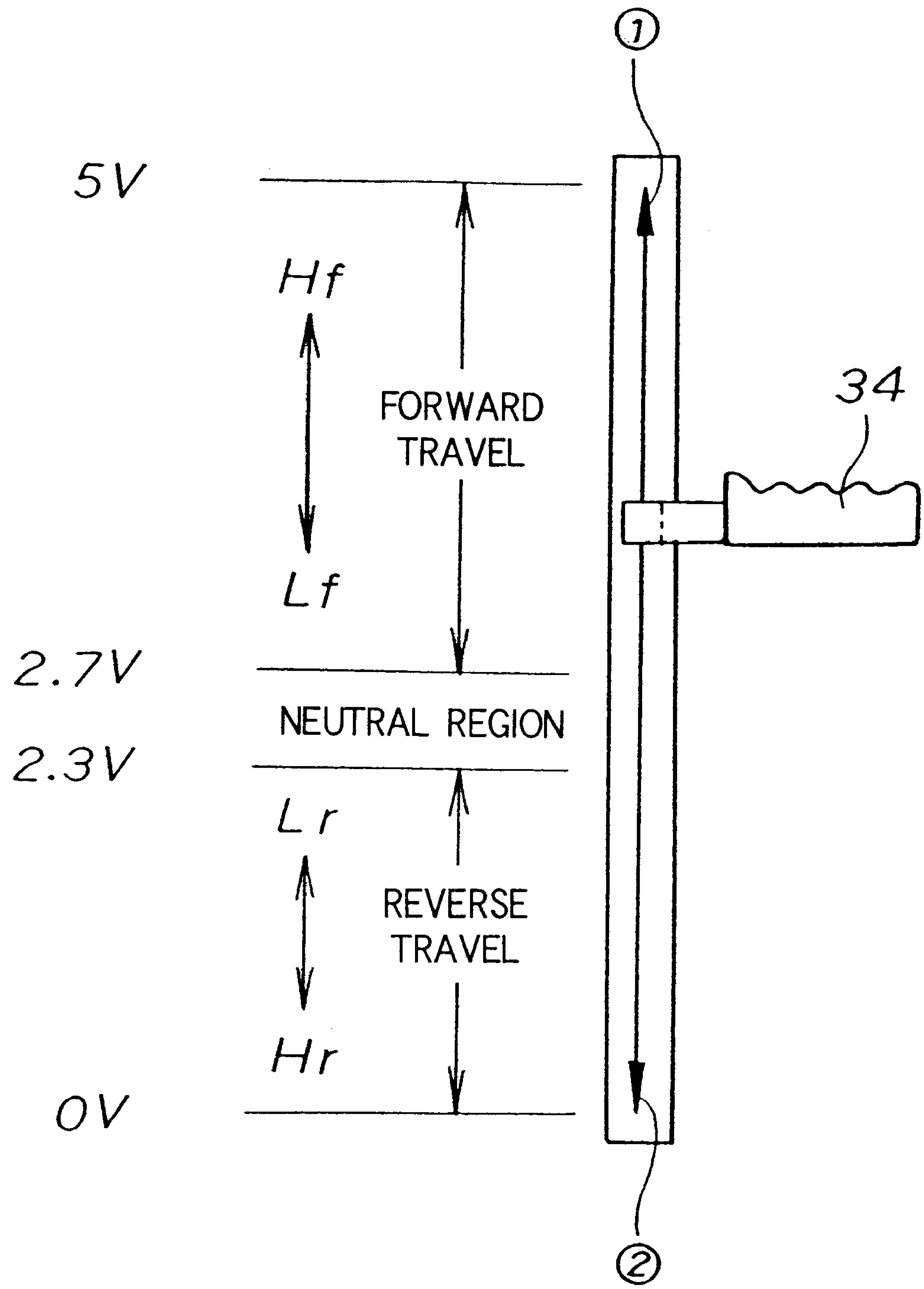


FIG. 4



45
13
14
43
18
17
E
48
12
15L
15R
23L
25L
53L
51L
M
53R
25R
23R
51R
M
55R
55L
54L
52L
54R
52R
39L
42
31
44
28
39R
37L
38
35
49
34
37R

FIG.5



①
5V
Hf
FORWARD TRAVEL
34
Lf
2.7V
NEUTRAL REGION
2.3V
Lr
REVERSE TRAVEL
Hr
0V
②

FIG.6A

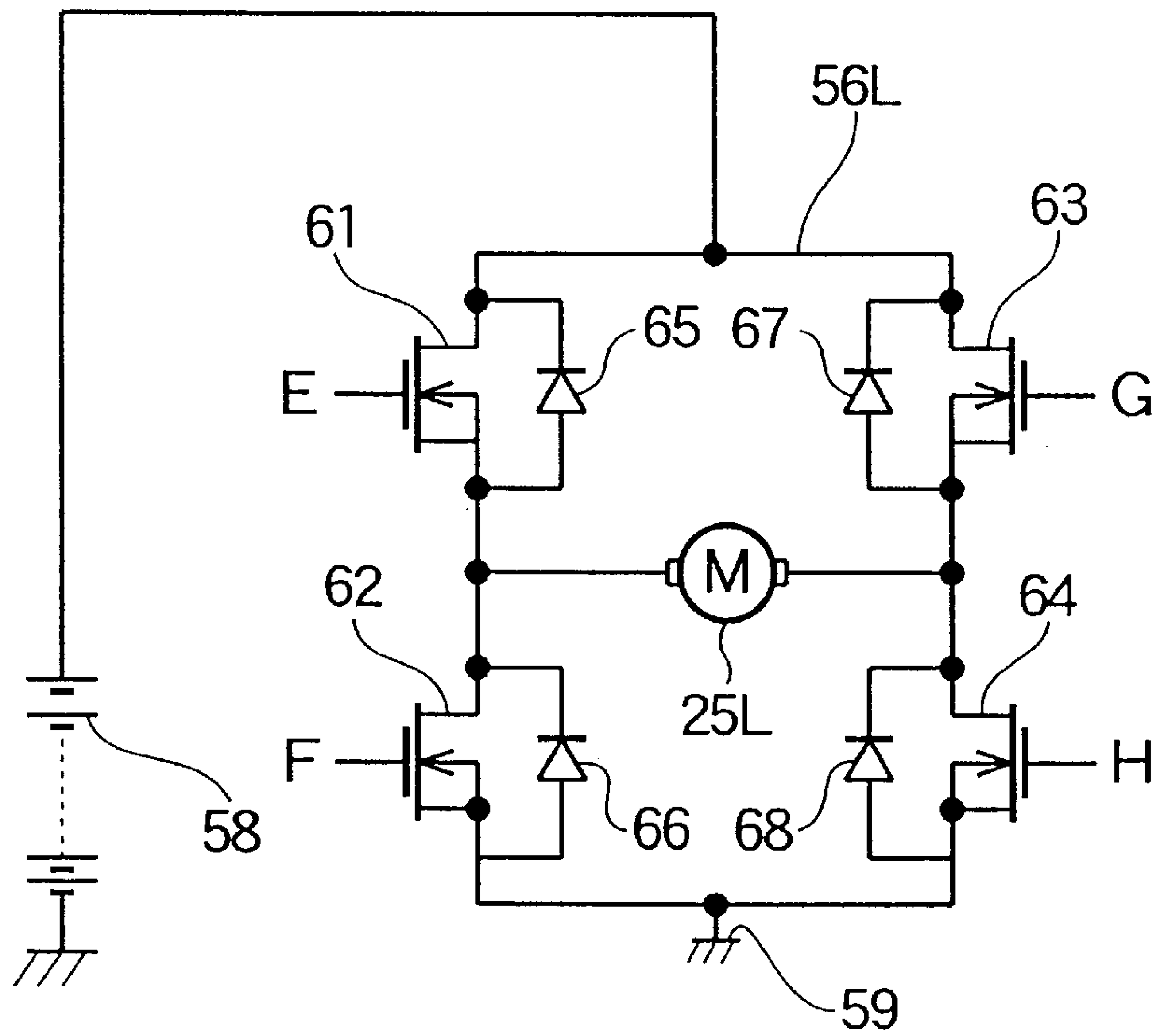


FIG.6B

MODE NAME	DRIVING ELEMENTS			
	E	F	G	H
SHORT CIRCUIT BRAKE MODE	OFF	ON	OFF	ON
FORWARD MODE	ON	OFF	OFF	ON
REVERSE MODE	OFF	ON	ON	OFF
FREE MODE	OFF	OFF	OFF	OFF

FIG. 7A

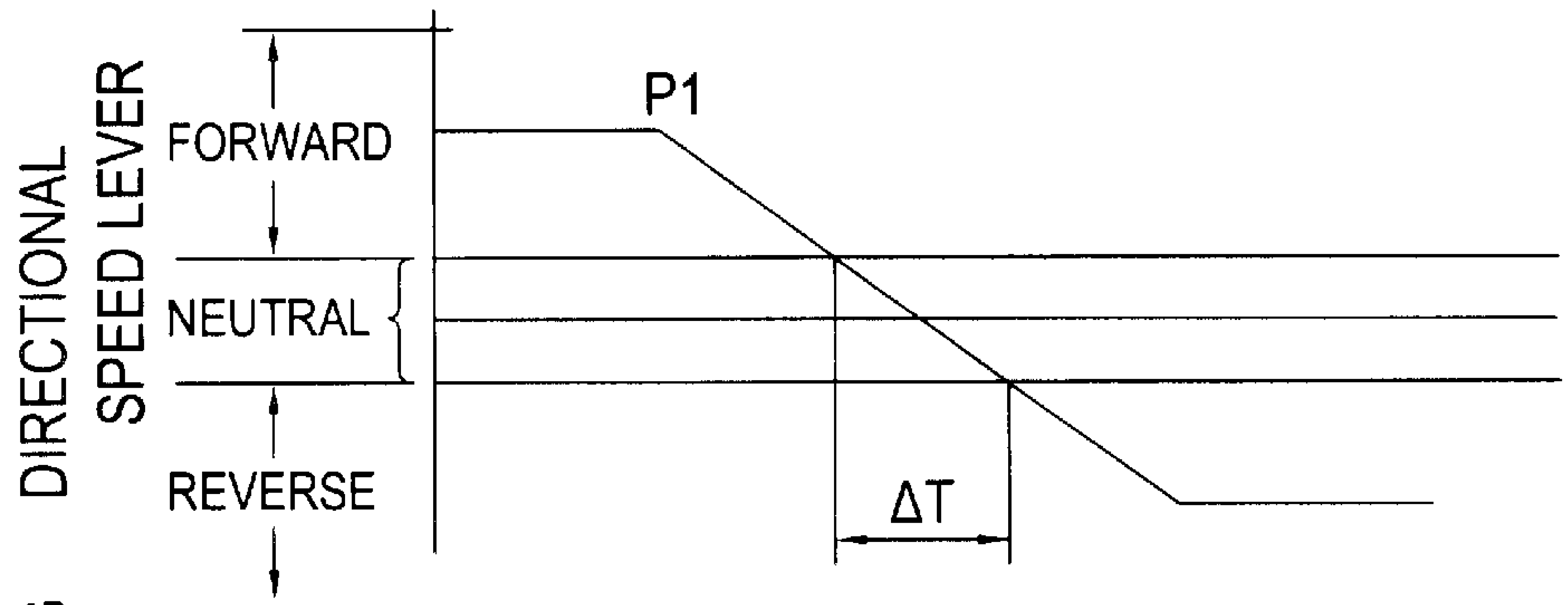


FIG. 7B

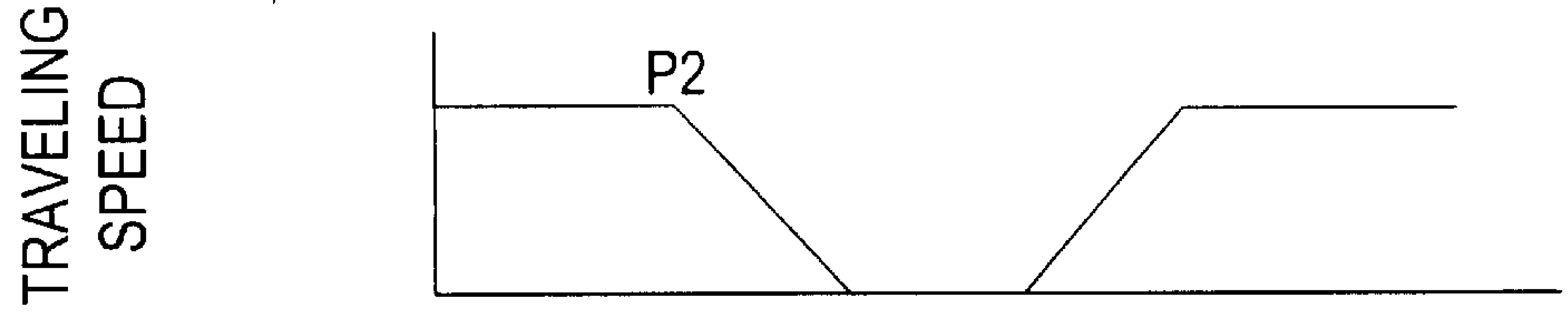


FIG. 7C

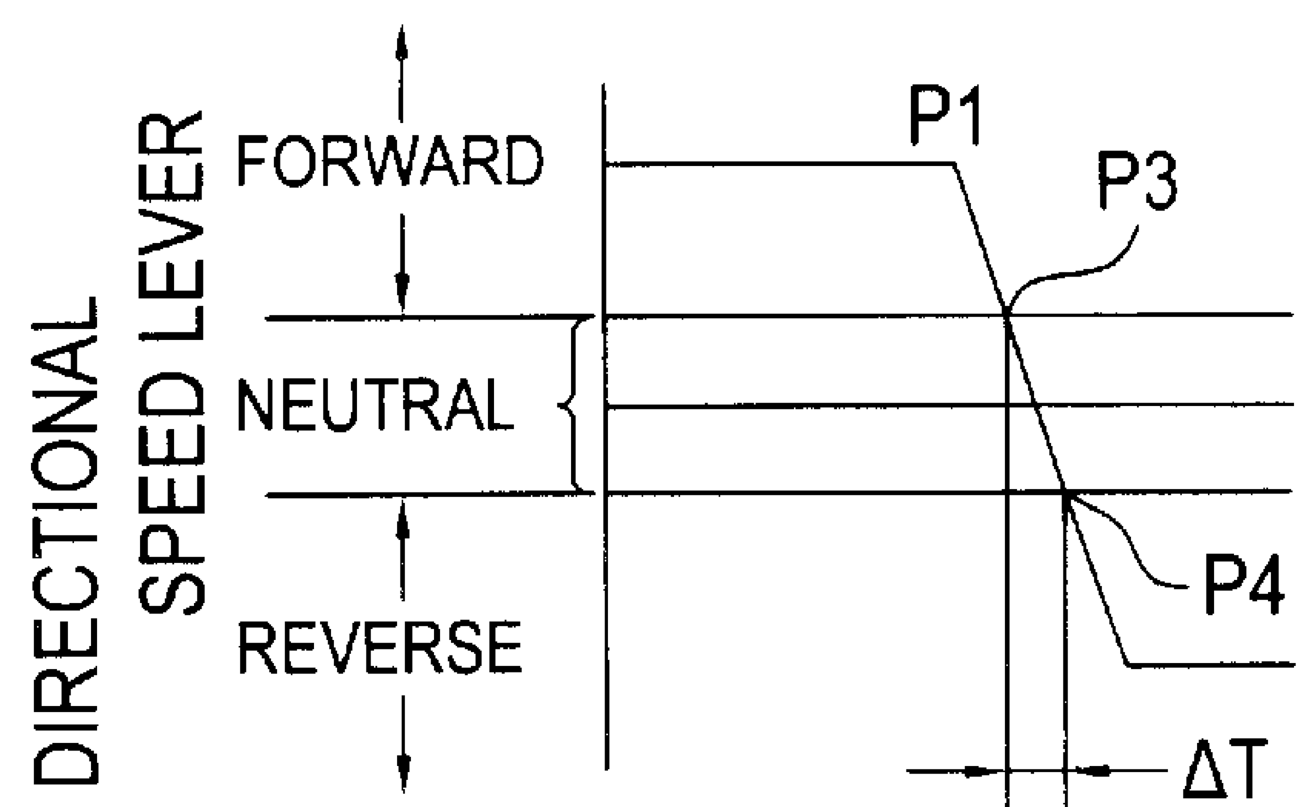


FIG. 7D

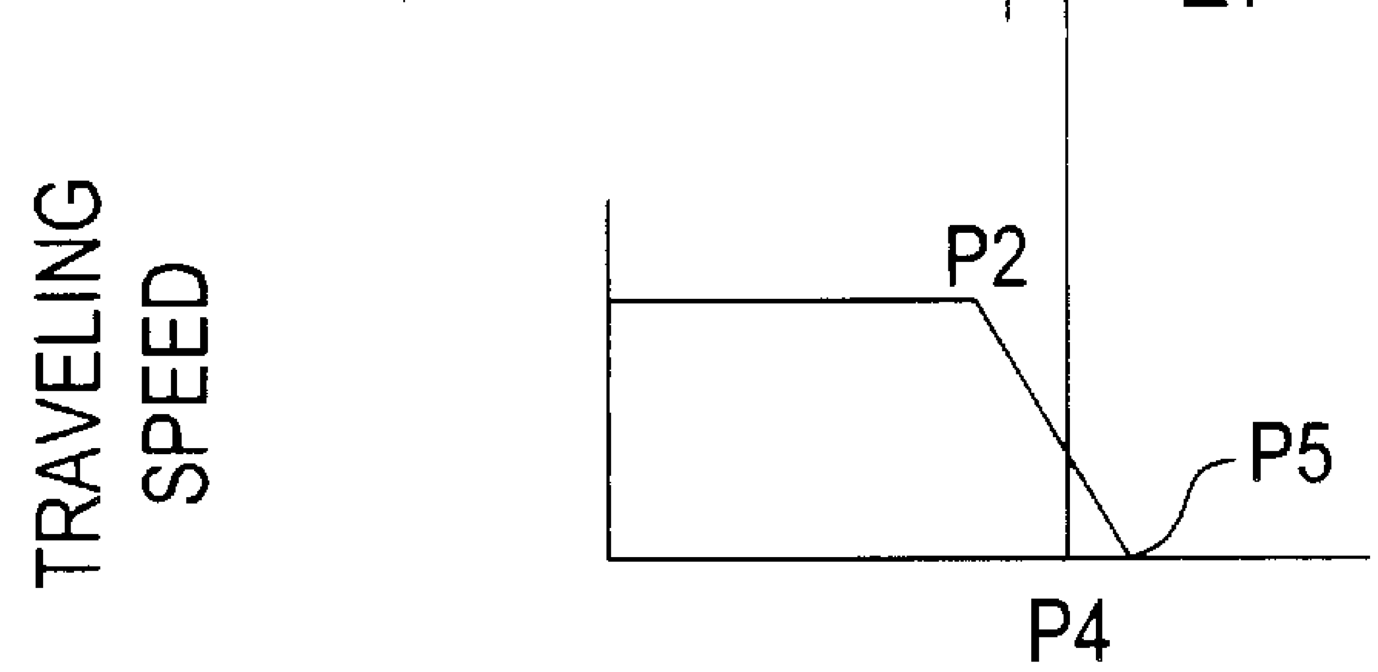


FIG. 7E

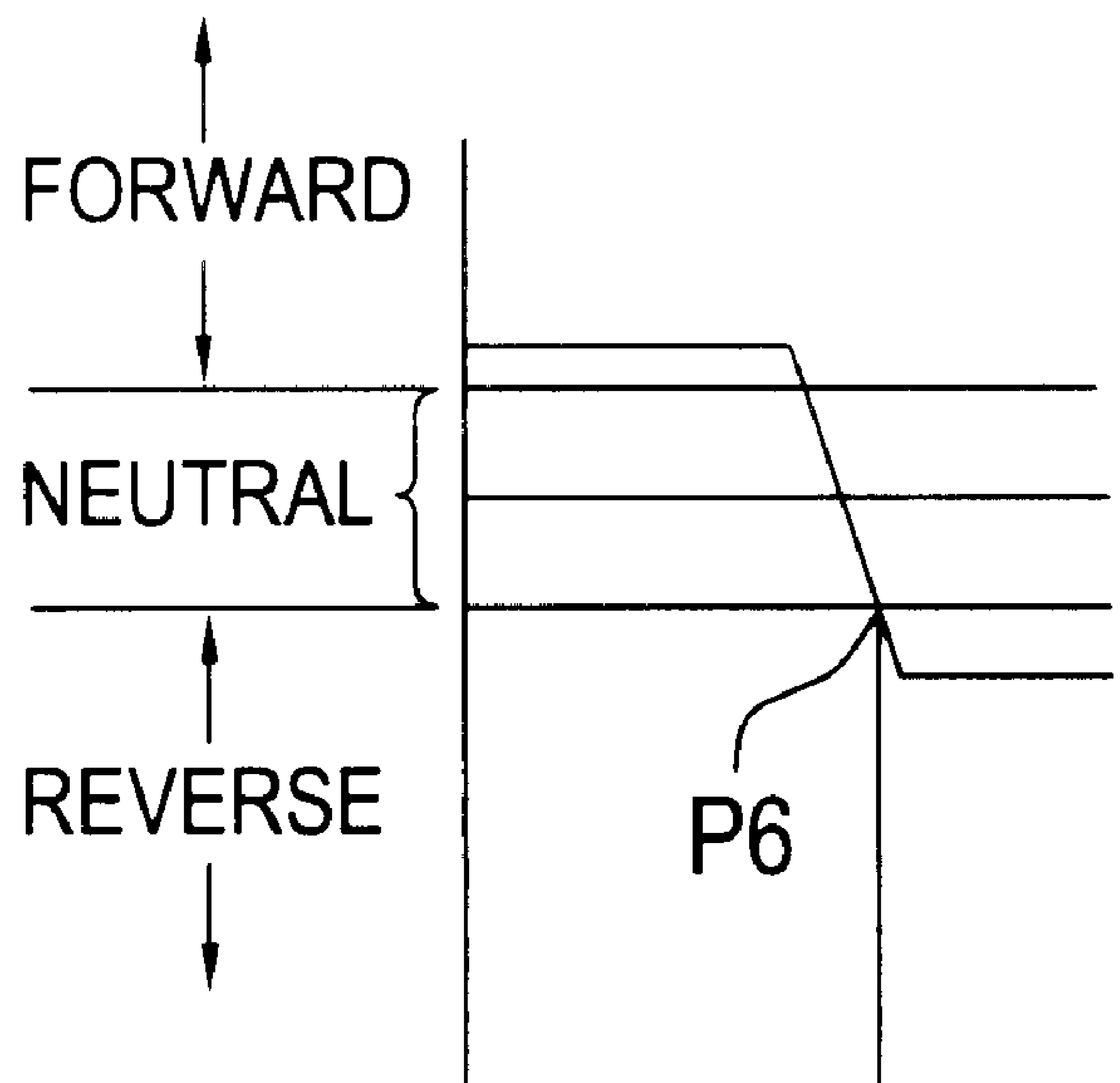


FIG. 7F

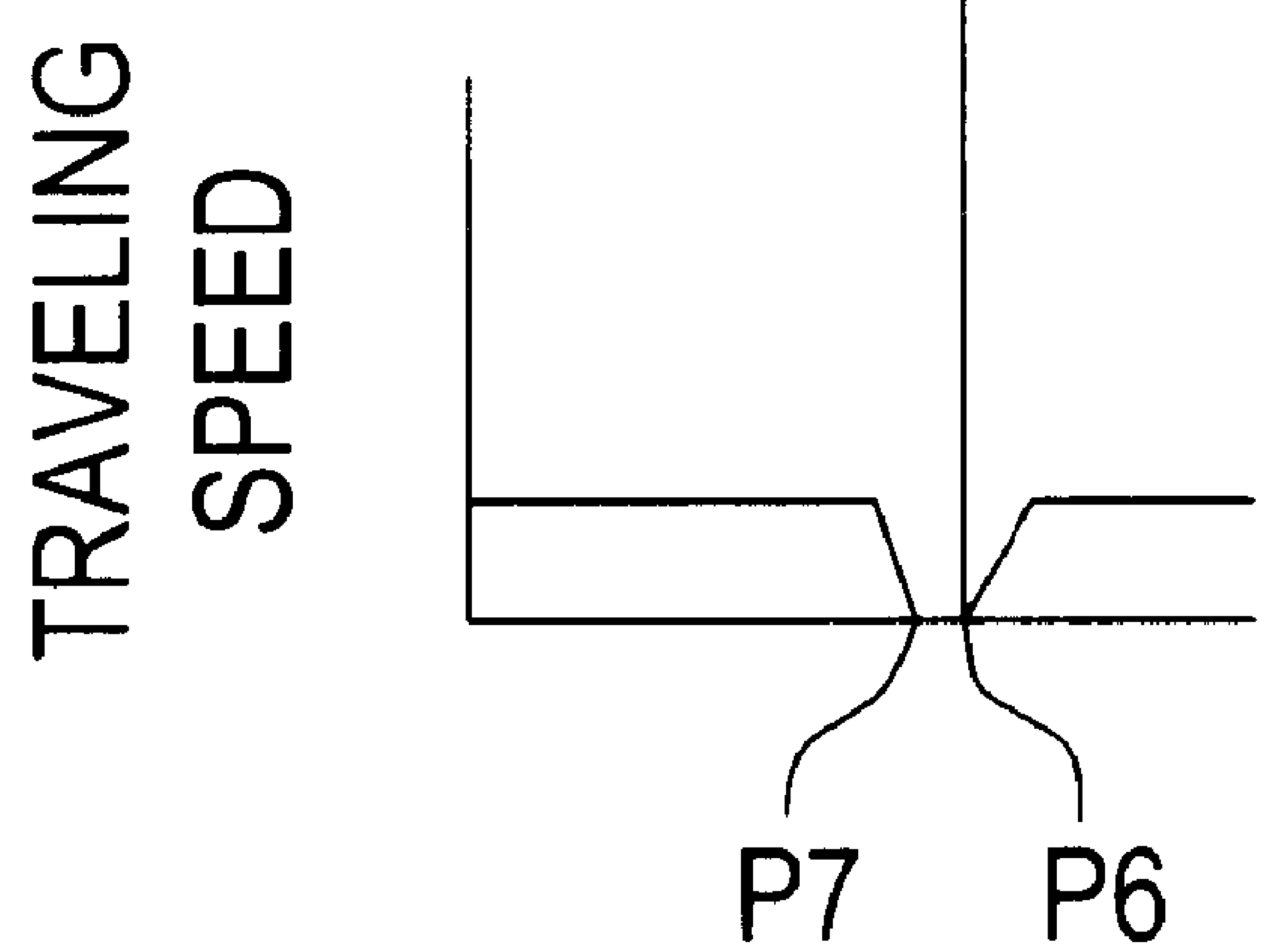


FIG. 8

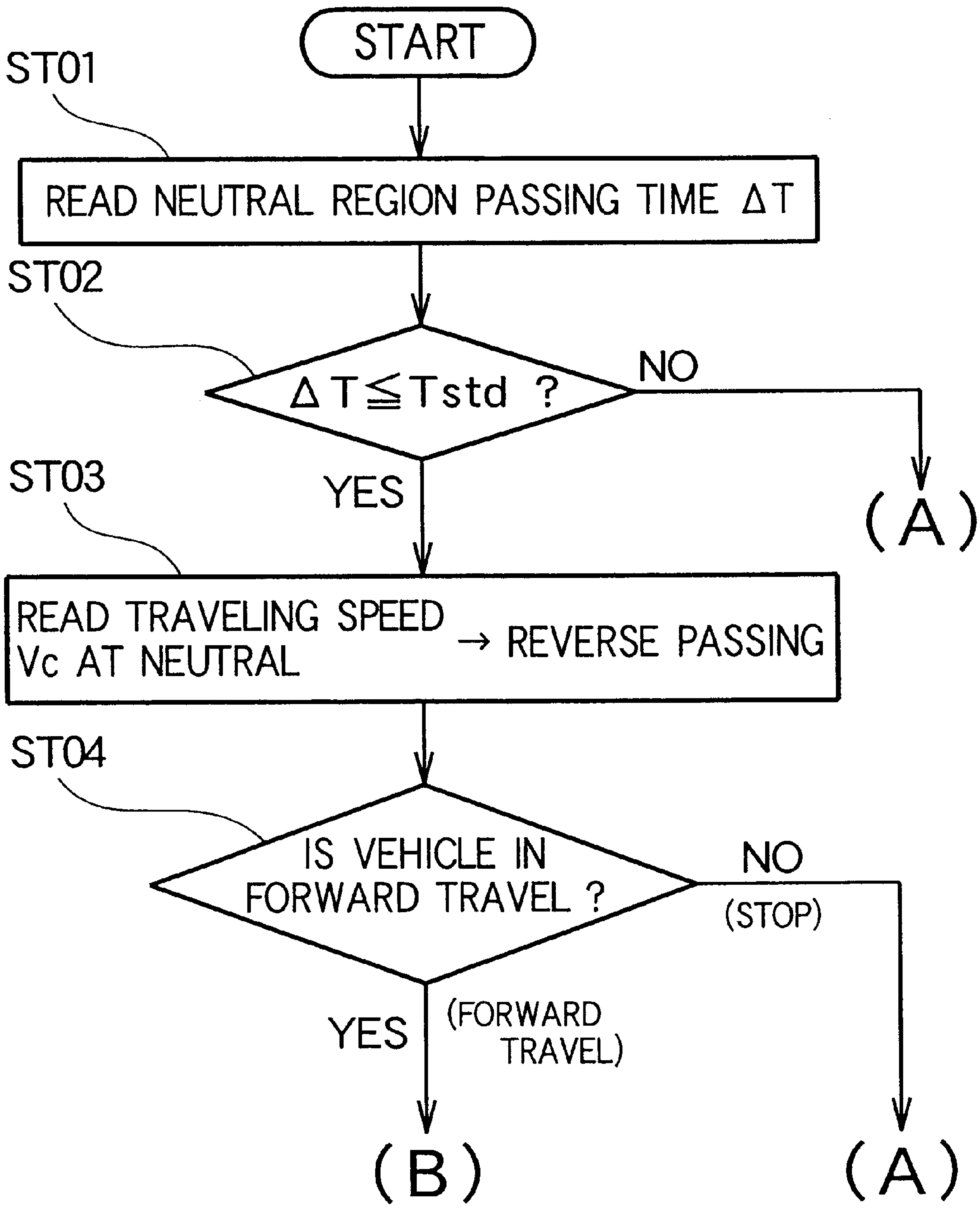

START
ST01
READ NEUTRAL REGION PASSING TIME ΔT
ST02
ΔT≦Tstd ?
NO
(A)
YES
ST03
READ TRAVELING SPEED Vc AT NEUTRAL → REVERSE PASSING
ST04
IS VEHICLE IN FORWARD TRAVEL ?
NO
(STOP)
YES
(FORWARD TRAVEL)
(B)
(A)

FIG. 9A

FIG. 9B

FIG. 9C

FIG. 9D

FIG. 9E

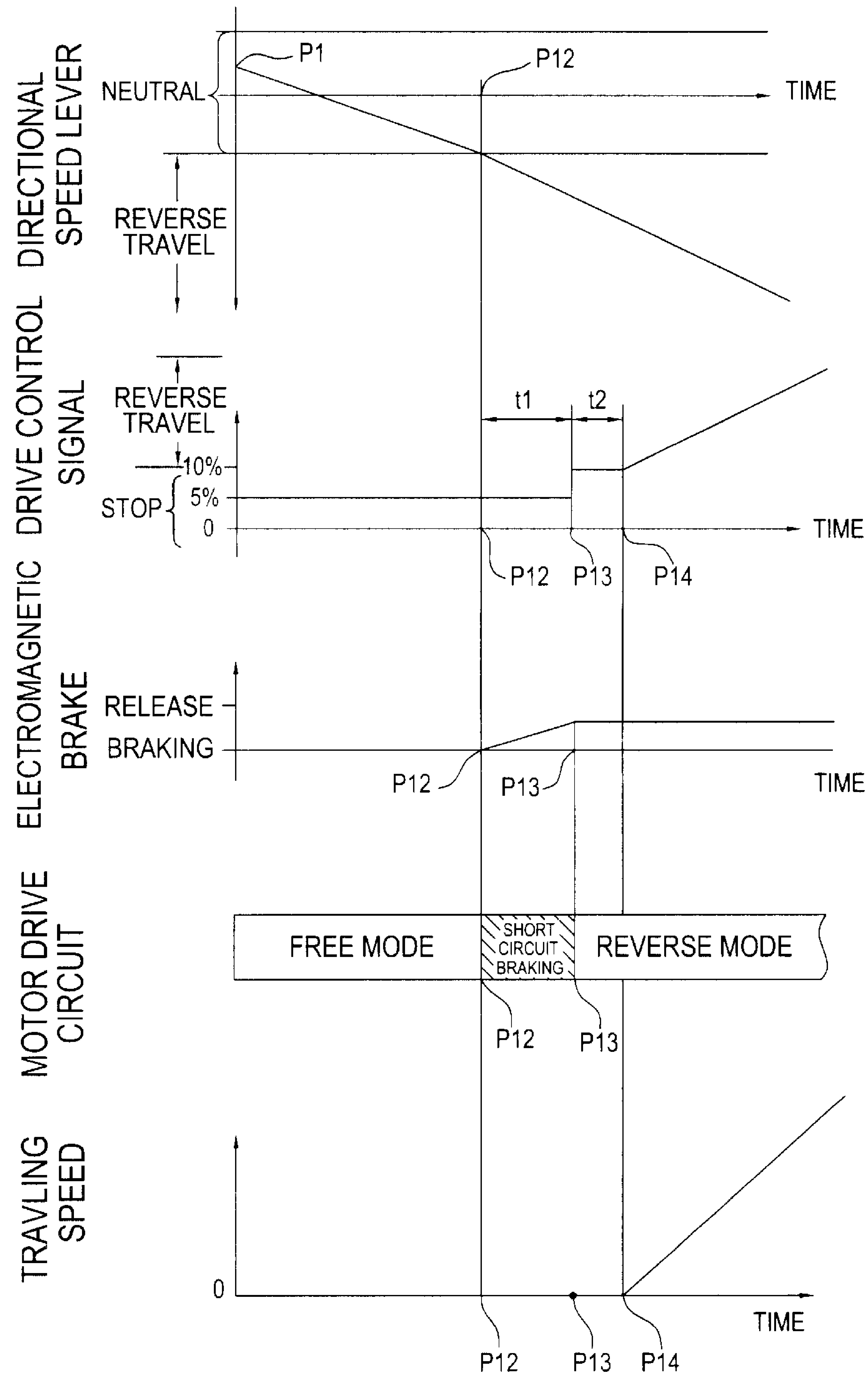


FIG. 10

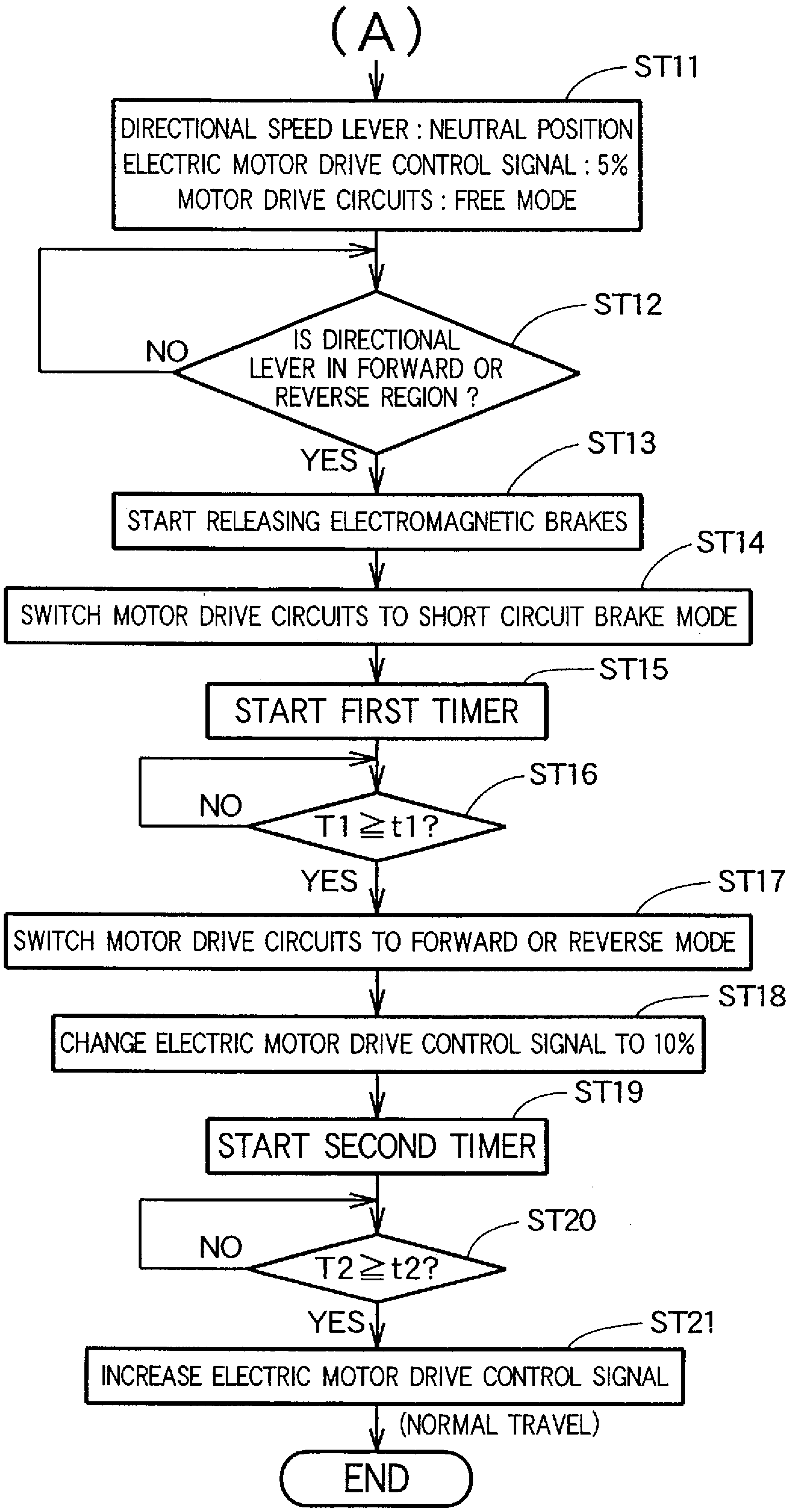

(A)
ST11
DIRECTIONAL SPEED LEVER : NEUTRAL POSITION
ELECTRIC MOTOR DRIVE CONTROL SIGNAL : 5%
MOTOR DRIVE CIRCUITS : FREE MODE
ST12
IS DIRECTIONAL LEVER IN FORWARD OR REVERSE REGION ?
NO
YES
ST13
START RELEASING ELECTROMAGNETIC BRAKES
ST14
SWITCH MOTOR DRIVE CIRCUITS TO SHORT CIRCUIT BRAKE MODE
ST15
START FIRST TIMER
ST16
T1≧t1?
NO
YES
ST17
SWITCH MOTOR DRIVE CIRCUITS TO FORWARD OR REVERSE MODE
ST18
CHANGE ELECTRIC MOTOR DRIVE CONTROL SIGNAL TO 10%
ST19
START SECOND TIMER
ST20
T2≧t2?
NO
YES
ST21
INCREASE ELECTRIC MOTOR DRIVE CONTROL SIGNAL
(NORMAL TRAVEL)
END

FIG. 11A

FIG. 11B

FIG. 11C

FIG. 11D

FIG. 11E

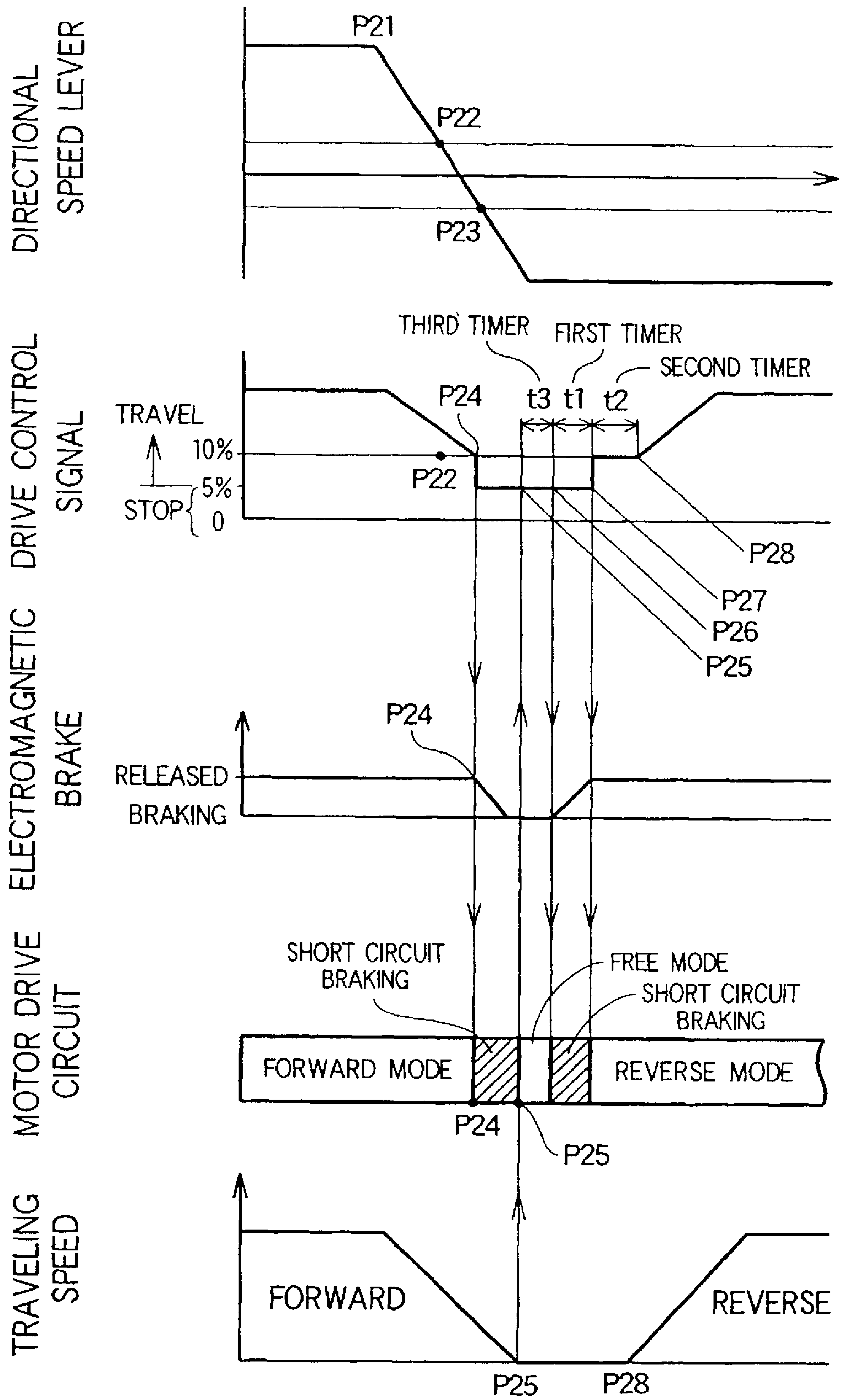
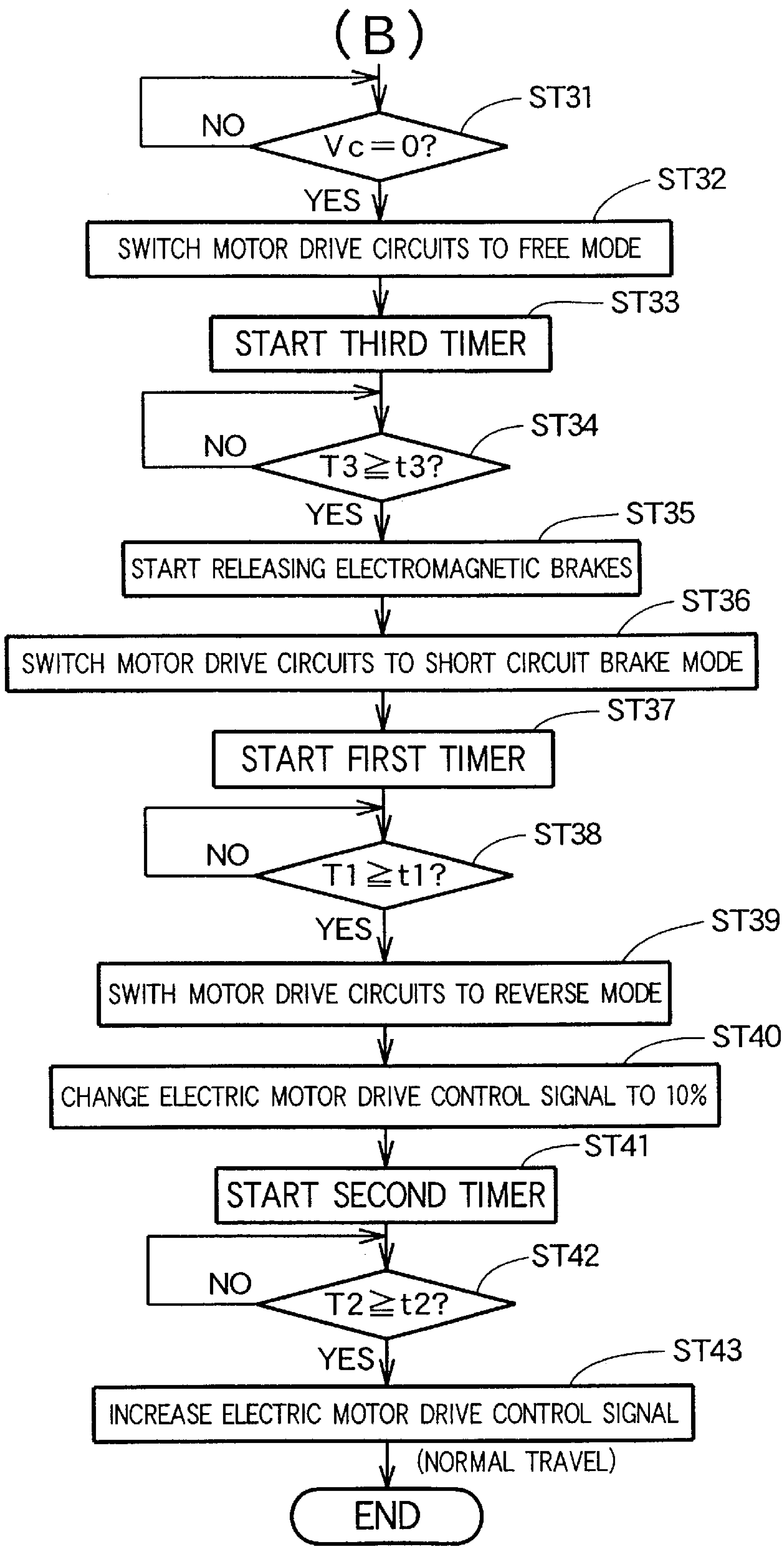


FIG.12


(B)
Vc=0?
ST31
NO
YES
SWITCH MOTOR DRIVE CIRCUITS TO FREE MODE
ST32
START THIRD TIMER
ST33
T3≧t3?
ST34
NO
YES
START RELEASING ELECTROMAGNETIC BRAKES
ST35
SWITCH MOTOR DRIVE CIRCUITS TO SHORT CIRCUIT BRAKE MODE
ST36
START FIRST TIMER
ST37
T1≧t1?
ST38
NO
YES
SWITH MOTOR DRIVE CIRCUITS TO REVERSE MODE
ST39
CHANGE ELECTRIC MOTOR DRIVE CONTROL SIGNAL TO 10%
ST40
START SECOND TIMER
ST41
T2≧t2?
ST42
NO
YES
INCREASE ELECTRIC MOTOR DRIVE CONTROL SIGNAL
ST43
(NORMAL TRAVEL)
END

ELECTRIC VEHICLE

FIELD OF THE INVENTION

The present invention relates to an improvement in electric vehicles driven by electric motors, and more particularly, relates to control in switching an electric vehicle in forward travel to reverse travel.

BACKGROUND OF THE INVENTION

An electric vehicle of this kind is disclosed, for example, in Japanese Patent Laid-Open Publication No. HEI-3-98404 entitled "Compact Electric Vehicle." This electric vehicle includes an electric motor as a driving source, a drive circuit for the electric motor, an electromagnetic brake which releases the brake when being energized, a controller for controlling the electric motor and the electromagnetic brake, an acceleration setting volume, and a switch for switching between forward and reverse travel which allows a choice between forward or reverse travel and selection from among low, middle and high speeds.

In order to switch the direction of the electric vehicle from forward travel to reverse travel by the switch, the acceleration setting volume is returned to zero (zero motor rotation) before forward/reverse switching of the switch.

For some reason, however, the switch can be switched from forward travel to reverse travel without returning the acceleration setting volume to zero. This requires reversing the polarity of a motor drive circuit, resulting in a heavy load applied to switching elements constituting the motor drive circuit. It is thus necessary to use large-capacity switching elements endurable to the load.

Large-capacity switching elements inevitably cost high and have large size. This undesirably boosts the cost of the vehicle. An electric vehicle which allows reduction in load applied to a motor control circuit is thus desired.

SUMMARY OF THE INVENTION

According to the present invention, there is provided an electric vehicle driven by electric motors, which comprises: a directional speed member for instructing forward travel, neutral and reverse travel of the vehicle and adjusting the speed of the vehicle; the electric motors which operate in accordance with the operation of the directional speed member; and a controller for performing such control as, when two conditions are satisfied that time required for the directional speed member to pass through a neutral region is shorter than a threshold and the electric motors are still rotating in a forward direction at a point of time when the directional speed member is shifted from the neutral region to a reverse region, waiting until the speed of the electric motors becomes zero, and, after a lapse of time required for forward/reverse switching of the motor drive circuits since the speed of the electric motors reaches zero, shifting to normal reverse operation.

This invention thus first determines whether the directional speed member is switched at a "normal" speed or a "high speed." When the "high speed" switching is found, this invention waits until the speed of the electric motors becomes zero. This invention further waits until time required for forward/reverse switching of the motor circuits has elapsed and then performs reverse control. This allows reduction in electrical load applied to the motor circuits, allowing reduction in capacity of switching elements and reduction in cost of the circuits.

However, when the traveling speed of the vehicle is low, since switching of the directional speed member from forward travel to reverse travel at a high speed does not apply a large load to the motor drive circuits, the vehicle is operated during a period of time required for forward/reverse switching of the motor drive circuits, resulting in smoothness of the operation.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the present invention will be described in detail below, by way of example only, with reference to the accompanying drawings, in which:

FIG. **1** is a plan view of a snow removal machine having an engine and electric motors, exemplifying an electric vehicle of the present invention;

FIG. **2** is a view taken in the direction of arrow **2** in FIG. **1**, illustrating a control section of the snow removal machine;

FIG. **3** is a view taken in the direction of arrow **3** in FIG. **2**, illustrating a left turn control lever and a drive preparatory lever;

FIG. **4** is a control system diagram of the snow removal machine shown in FIG. **1**;

FIG. **5** is a diagram illustrating the operating range of a directional speed lever shown in FIG. **4**;

FIGS. **6**A and **6**B are, respectively, an electric motor drive circuit according to the present invention and a mode table;

FIGS. **7**(*a*) to **7**(*f*) are graphs illustrating the relationship between the directional speed lever of the present invention and traveling speed;

FIG. **8** is a flowchart corresponding to FIGS. **7**(*a*) to **7**(*f*), of determining whether or not the directional speed lever is switched at a high speed;

FIGS. **9**(*a*) to **9**(*e*) are time charts illustrating normal starting control of the present invention;

FIG. **10** is a control flowchart corresponding to FIGS. **9**(*a*) to **9**(*e*);

FIGS. **11**(*a*) to **11**(*e*) are time charts illustrating starting control at high-speed switching of the directional speed lever; and

FIG. **12** is a control flowchart corresponding to FIG. **11**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following description is merely exemplary in nature and is in no way intended to limit the invention, its application or uses.

Initial reference is made to FIG. **1** illustrating a snow removal machine **10** exemplifying an electric vehicle of the present invention. The snow removal machine **10** includes an engine **12** mounted on a machine body **11**. The snow removal machine **10** further includes a working section consisting of an auger **13** and a blower **14** provided at the front of the machine body **11**, crawlers **15**L and **15**R provided at the left and right of the machine body **11**, and a control panel **16** provided at the rear of the machine body **11**. The snow removal machine **10** is a walk-behind working machine to be led by an operator walking behind the control panel **16**.

The engine **12** drives a generator **17** for rotation and drives the auger **13** and the blower **14** for rotation via an electromagnetic clutch **18** and a belt **19**.

Electric power produced by the generator **17** is supplied to left and right electric motors **25**L and **25**R for driving left and right driving wheels **23**L and **23**R via a battery **43** (See FIG. **4**) arranged below the control panel **16**.

The auger **13** collects snow accumulating on the ground to the center. The blower **14** throws the snow collected by the auger **13** outside of the machine via a shooter **21**. The auger **13** is covered by an auger housing **22**.

The left crawler **15**L is wound around and runs between the left driving wheel **23**L and a left driven wheel **24**L. In this embodiment, the left driving wheel **23**L is rotated in forward and reverse directions by the left electric motor **25**L. The right crawler **15**R is wound around and runs between the right driving wheel **23**R and a right driven wheel **24**R. The right driving wheel **23**R is rotated in forward and reverse directions by the right electric motor **25**R.

In a conventional snow removal machine, a single engine (a gasoline engine or a diesel engine) drives both a working system (auger rotating system) and a driving system (crawler driving system). In this embodiment, the engine **12** drives the working system (auger rotating system), and the electric motors **25**L and **25**R drive the driving system (crawler driving system).

Electric motors are suitable for traveling speed control, turning control and forward and reverse travel switching control of the snow removal machine **10**. A powerful internal combustion engine is suitable for powering the working system susceptible to rapid load change.

As shown in FIG. **2**, the control panel **16** has, on the front surface of a control box **27** to face an operator, a main switch **28**, an engine choke **29**, a clutch control button **31** and other components. On the top surface of the control box **27**, a snow throwing direction adjustment lever **32**, an auger housing orientation adjustment lever **33**, a directional speed lever **34** as a directional speed instructing member for the driving system, and an engine throttle lever **35** for the working system are provided. On the right of the control box **27**, a grip **36**R and a right turn control lever **37**R are provided. On the left of the control box **27**, a grip **36**L, a left turn control lever **37**L and a drive preparatory lever **38** are provided.

The left and right turn control levers **37**L and **37**R are similar to brake levers, but cannot provide complete braking effects as will be described below. The left and right turn control levers **37**L and **37**R are operated for reducing the rotational speed of the left and right electric motors **25**L and **25**R to turn the machine body. Therefore those components are not referred to as brake levers but turn control levers.

The main switch **28** is a known switch into which a main key is inserted and rotated for starting the engine. The engine choke **29** can be pulled to increase the density of air-fuel mixture. The snow throwing direction adjustment lever **32** is operated for changing the direction of the shooter **21** (See FIG. **1**). The auger housing orientation adjustment lever **33** is operated for changing the orientation of the auger housing **22** (See FIG. **1**).

As shown in FIG. **3**, handling the left turn control lever **37**L can rotate an arm **39***a* of a potentiometer **39**L at an angle to a position shown by imaginary lines. The potentiometer **39**L produces electric information in accordance with the rotational position of the arm **39***a*.

The drive preparatory lever **38** is rotatable about a shaft **38***a* mounted to a handle **20** and is constantly biased by an extension spring **41** in a direction to turn a switch **42** off. Handling the drive preparatory lever **38** toward the left grip **36**L by the left hand of the operator turns the switch **42** on. In short, handling the drive preparatory lever **38** turns the switch **42** from off to on. The switched ON signal is supplied to a controller **44** shown in FIG. **4**. The controller **44** recognizes the completion of drive preparation upon receiving the ON signal.

FIG. **4** illustrates an electric system diagram of the snow removal machine according to the present invention. The controller **44** is provided in the control panel.

The engine **12** is started by rotation of a starter not shown connected to the battery **43** when the main switch **28** is turned on. The engine **12** drives the generator **17** for rotation, and the output power is supplied to the battery **43**.

The engine throttle lever **35** is connected to a throttle valve **48** via a throttle wire (not shown). The engine throttle lever **35** is operated to adjust the opening of the throttle valve **48**, adjusting the number of revolutions of the engine **12**.

The drive preparatory lever **38** is handled to turn the switch **42** on. The ON signal is supplied to the controller **44**. Handling the drive preparatory lever **38** allows the operation of the clutch control button **31**. With this state, the clutch control button **31** is operated to bring the electromagnetic clutch **18** of the working system **45** into a connecting state, driving the blower **14** and the auger **13** for rotation. Either releasing the drive preparatory lever **38** or operating the clutch control button **31** for disconnection brings the electromagnetic clutch **18** into a disconnecting state.

The snow removal machine of this embodiment has left and right electromagnetic brakes **51**L and **51**R as brakes corresponding to parking brakes of a common vehicle. The electromagnetic brakes **51**L and **51**R are brought into a braking state when the directional speed lever **34** is put in a neutral region. When the main switch **28** is in an on state (start position) and the drive preparatory lever **38** is handled, in other words, when the two conditions are satisfied, switching the directional speed lever **34** to a forward position or a reverse position brings the electromagnetic brakes **51**L and **51**R into a released state (non-braking state), propelling the snow removal machine forward or backward.

The directional speed lever **34** is shown in detail in FIG. **5**. From FIG. **5**, the directional speed lever **34** is movable between a forward region, a neutral region and a reverse region. In the forward region, Lf indicates low-speed forward travel and Hf high-speed forward travel. The forward traveling speed is adjustable between Lf and Hf. Specifically, the directional speed lever **34** is operated to adjust the number of revolutions of the left and right electric motors **25**L and **25**R via the controller **44** and left and right motor drivers **52**L and **52**R shown in FIG. **4**. In the reverse region, Lr indicates low-speed reverse travel and Hr high-speed reverse travel. Reverse traveling speed is controllable between low-speed reverse travel Lr and high-speed reverse travel Hr.

A potentiometer **49** shown in FIG. **4** is designed to generate, as shown in FIG. **5**, a voltage of 0 volt at the highest speed in reverse travel, a voltage of 5 volts at the highest speed in forward travel, and a voltage from 2.3 to 2.7 volts in the neutral region.

The controller **44** receives the position information of the directional speed lever **34** from the potentiometer **49** and controls the rotation direction and the rotational speed of the left and right electric motors **25**L and **25**R via the left and right motor drivers **52**L and **52**R. The rotational speeds of the left and right electric motors **25**L and **25**R are detected by rotation sensors **53**L and **53**R and the detection signals are fed back to the controller **44**. Based on the detection signals, the controller **44** controls the rotational speeds of the electric motors **25**L and **25**R to a predetermined value. As a result, the left and right driving wheels **23**L and **23**R rotate in a desired direction at a predetermined speed, propelling the vehicle.

Braking of the vehicle in travel is performed through the following steps. The motor drivers **52**L and **52**R of this embodiment include regenerative brake circuits **54**L and **54**R. In this embodiment, electrical switching changes the electric motors **25**L and **25**R to generators for power generation. Generating voltage higher than the battery voltage enables storing electric energy in the battery **43**. This is the operating principle of regenerative brakes.

The left potentiometer **39**L detects the degree of handling of the left turn control lever **37**L. In response to a signal detected by the left potentiometer **39**L, the controller **44** activates the left regenerative brake circuit **54**L and reduces the rotational speed of the left electric motor **25**L.

The right potentiometer **39**R detects the degree of handling of the right turn control lever **37**R. In response to a signal detected by the right potentiometer **39**R, the controller **44** activates the right regenerative brake circuit **54**R and reduces the rotational speed of the right electric motor **25**R.

The snow removal machine is thus turned left by handling the left turn control lever **37**L and is turned right by handling the right turn control lever **37**R.

Any of the following operations stops the travel of the snow removal machine.

i) Return the directional speed lever **34** to the neutral position.

ii) Release the drive preparatory lever **38**.

iii) Return the main switch **28** to the off position.

Short-circuiting brake circuits **55**L and **55**R are used for the stopping. The left short-circuiting brake circuit **55**L short-circuits the two poles of the electric motor **25**L. The short circuit brings the electric motor into a suddenly braked state. The right short-circuiting brake circuit **55**R operates the same.

Returning the main switch **28** to the off position after the snow removal machine stops traveling activates the electromagnetic brakes **51**L and **51**R to apply the parking brakes.

Now driving of the electric motors used in this embodiment will be described with reference to FIGS. **6**A and **6**B.

In FIG. **6**A, a high frame of a drive circuit **56**L of the electric motor **25**L (an upper half of the circuit) is connected to a power source **58**. A low frame (a lower half of the circuit) is connected to a ground **59**. In a left high frame and a left low frame, an E driving element **61** and an F driving element **62** are disposed, respectively. In a right high frame and a right low frame, a G driving element **63** and an H driving element **64** are disposed, respectively. Diodes **65** to **68** are connected in parallel with the E to H driving elements **61** to **64**, functioning as bypass circuits. The E to H driving elements **61** to **64** are switched on and off in response to control signals.

Field effect transistors (FET) are suitable for the E to H driving elements **61** to **64**. Ordinary transistors are low-impedance devices activated by current while FETs are high-impedance devices activated by voltage. Because of their high impedance, FETs are generally suitable for being interposed in the circuit **56**L as shown in the figure. However, FETs have such disadvantages as operating slowly as compared with other electronic components and requiring long operating time. Time equivalent to the operating time is herein referred to as t2. The time t2 will be described below.

FIG. **6**B is a mode table for the electric motor drive circuits, illustrating mode names on the left and the ON or OFF states of the E to H driving elements on the right.

In a short circuit brake mode, the F and H driving elements are turned ON and the E and G driving elements are turned OFF. In FIG. **6**A, the power source **58** is isolated from the electric motor **25**L to form a short circuit in the low frame. A sudden brake is thus applied to the electric motor **25**L. This state is referred to as a short circuit brake.

In a forward mode, the E and H driving elements are turned ON and the F and G driving elements are turned OFF. In FIG. **6**A, a current flows through the E driving element, the electric motor **25**L and the H driving element **64** in this order, forwardly rotating the electric motor **25**L. In a reverse mode, the opposite conditions reversely rotate the electric motor **25**L.

In a free mode, the E to H driving elements are all turned OFF. No current flow through the electric motor allows its idle rotation.

Now determination whether the directional speed member is switched at a "normal" speed or a "high speed" will be first described with FIGS. **7** and **8**. Normal operation control at the "normal" speed switching will be described with FIGS. **9** and **10**. Operation control of the present invention at the "high speed" switching will be described with FIGS. **11** and **12**.

FIGS. **7**(*a*) to **7**(*f*) are graphs illustrating the relationship between the directional speed lever of this embodiment and traveling speed. All of the horizontal axes are time axes. FIGS. **7**(*a*) and **7**(*b*) correspond to shifting of the directional speed lever at the "normal" speed. FIGS. **7**(*c*) to **7**(*f*) correspond to shifting of the directional speed lever at the "high speed."

In FIG. **7**(*a*), the vertical axis indicates positions of the directional speed lever, showing shifting of the directional speed lever in a forward position from a point **P1** to a reverse position at a relatively low speed.

In FIG. **7**(*b*), the vertical axis indicates traveling speed which almost precisely follows' the positional change of the directional speed lever as being gradually reduced from a point **P2**.

FIG. **7**(*c*) illustrates switching of the directional speed lever in a forward high-speed position to a reverse high-speed position at a high speed, showing the lever's getting into the neutral region at a point **P3** and getting out of the neutral region at a point **P4**.

FIG. **7**(*d*) illustrates traveling speed corresponding to FIG. **7**(*c*), showing that the traveling speed starts declining at **P2** but the effect of an inertial force due to the vehicle mass causes a point **P5** where the traveling speed becomes zero to be behind **P4** (equal to **P4** in FIG. **7**(*c*)). Between **P4** and **P5**, the directional speed lever is in the reverse region but the electric motors are still in forward rotation. Under this state, reversing the rotation of the electric motors must be avoided; otherwise electrical overload will occur.

In FIG. **7**(*c*), time ΔT from **P3** to **P4** is a period of time required for the directional speed lever to pass through the neutral region. When the time ΔT is within a threshold Tstd (this value is used in the next figure), it is determinable that the directional speed lever is shifted from forward travel to reverse travel at a "high speed."

FIG. **7**(*e*) illustrates switching of the directional speed lever in a forward low-speed position to a reverse low-speed position at a high speed.

FIG. **7**(*f*) illustrates traveling speed corresponding to FIG. **7**(*e*), in which the traveling speed becomes zero at a point **P7**. In this example, an inertial force is small because speed reduction is started from a low speed and the speed is immediately becomes zero without much receiving the effect of the inertial force. **P7** is ahead of a point **P6** (in FIG.

7(*e*), showing shifting from the neutral region to the reverse region). This is completely different from the state in FIG. 7(*d*). Specifically, at **P6** in FIG. 7(*f*), the traveling speed is already zero. Starting reverse travel at **P6** is thus not harmful, causing no electrical overload.

FIG. **8** illustrates an operation control flowchart corresponding to FIG. **7**.

In step (hereinafter abbreviated as ST) **01**, read neutral region passing time ΔT (See FIGS. **7**(*a*) and **7**(*c*)).

In ST**02**, determine whether or not the neutral region passing time ΔT is equal to or lower than the threshold Tstd. When the answer is NO, the speed is assumed to be "normal," and proceed to ST**11** in FIG. **10**. When YES, proceed to ST**03**.

In ST**03**, read a traveling speed Vc of the electric vehicle during shifting from the neutral region to the reverse region. Specifically, read signals from the rotation sensors **53**L and **53**R shown in FIG. **4**.

In ST**04**, determine whether or not the vehicle is still in forward travel. Specifically, when Vc is not zero and the rotation direction of the electric motors is forward, the vehicle is assumed to be in forward travel. When NO, determine that it is allowable to shift to normal operation for the reason described with FIG. **7**(*f*), and proceed to ST**11** shown in FIG. **10**. When YES, proceed to ST**31** shown in FIG. **12**.

FIGS. **9**(*a*) to **9**(*e*) are time charts illustrating normal starting control of this embodiment, in which the horizontal axes are time axes.

In FIG. **9**(*a*), the vertical axis indicates positions of the directional speed lever. Manual shifting of the directional speed lever in the neutral region (the lever may have been shifted from the forward region to the neutral region) to the reverse region is started at a point **P1** on the horizontal axis. At a point **P12** on the horizontal axis, the lever passes the boundary (See 2.3V in FIG. **5**) between the neutral region and the forward region. Thereafter the directional speed lever is continuously shifted.

In FIG. **9**(*b*), the vertical axis indicates a drive control signal to the electric motors. The drive control signal is a PI drive control signal in proportional-plus-integral (PI) control and is a PID drive control signal in proportional-plus-integral-plus-derivative (PID) control. In this embodiment, drive control is performed in a range from 10% to 90% of the full scale of 100% with the lowermost 10% and the uppermost 10% cut. Since the directional speed lever is in the neutral region before **P12** in FIG. **9**(*a*), the drive control signal in FIG. **9**(*b*) is set at 5%, less than 10%. Although the drive control signal may be 0, setting it at 5% is useful for detecting failure such as breaking of wire. Specifically, it becomes possible to recognize a normal state at 5% and braking of wire at less than 5%.

In FIG. **9**(*b*), the drive control signal is increased to 10% at a point **P13** at which time t1 has elapsed since **P12**. The time t1 is releasing-required time between the start of release of the electromagnetic brakes and the completion of the release. Measurements of the time required to switch the electromagnetic brakes from the braking state to the released state vary because of variations in their mechanical components. A value artificially determined based on an average value of the measured values is used as the time t1. Time t2 is determined in the same manner.

The time t1 depending on the size and structure of the electromagnetic brakes is set at about several milliseconds to dozens of milliseconds. The time t2 is similarly set at about several milliseconds to dozens of milliseconds.

In FIG. **9**(*b*), the drive control signal is turned to increase at a point **P14** at which the time t2 has elapsed since **P13**. It seems good to increase the drive control signal to 10% or more in FIG. **9**(*b*) immediately after the directional speed lever reaches **P12**, going beyond the neutral region in FIG. **9**(*a*). This embodiment, however, provides waiting time (t1+t2) on purpose.

FIG. **9**(*c*) illustrates the operating state of the electromagnetic brakes. Up to **P12**, since the directional speed lever in FIG. **9**(*a*) is in the neutral region, the electromagnetic brakes are in the braking state at a command from the controller. At **P12**, the controller starts releasing the electromagnetic brakes, providing an upward slope of the curve toward releasing. At **P13**, the electromagnetic brakes complete the releasing. The time between **P12** and **P13** thus agrees to the time t1 required to release the electromagnetic brakes.

FIG. **9**(*d*) is a diagram illustrating mode variation of the motor drive circuits. Up to **P12**, the motor drive circuits are in the free mode (See FIG. **6**B) at a command from the controller. In the free mode, the electric motors are idly rotatable. From **P12** to **P13**, the motors are in the short circuit brake mode (See FIG. **6**B) at a command from the controller. In FIG. **9**(*c*), since the electromagnetic brakes are released between **P12** and **P13**, the short circuit brakes are applied instead. This brings the electric motors into the braked state.

In FIG. **9**(*e*), the vertical axis indicates the traveling speed of the vehicle. At the point (**P14**) in FIG. **9**(*b*) where the drive control signal exceeds 10%, the traveling speed in FIG. **9**(*e*) exceeds 0 and the vehicle is in a traveling state.

In this example, the provision of the time t1 can prevent an occurrence of such an inconvenience that the electric motors are brought into an operating state while the electromagnetic brakes are in the braking state. This prevents brake drag, extending the life of the electromagnetic brakes.

Further, the provision of the time t2 enables gaining time during which the motors are brought into actual rotation from the short circuit brake mode. This allows a reduction in electrical load applied to the driving elements **61** to **64** shown in FIG. **6**A, extending the life or reducing the size of the driving elements **61** to **64**.

Another point is that in FIG. **9**(*e*), since the drive control signal to the electric motors is 5% between **P12** and **P13** (See FIG. **9**(*b*)), the electric motors do not produce torque although being in the short circuit braked state. Between **P13** and **P14**, the drive control signal to the electric motors is 10% (See FIG. **9**(*b*)) and the circuits are in the forward mode, so that small torque just before starting is produced. Between **P13** and **P14**, a force against the external force (small torque insufficient for travel) is thus generated by the electric motors in place of the short circuit brakes. As a result, the vehicle is prevented from rolling back on a grade also between **P13** and **P14**.

FIG. **10** is an operation control flowchart corresponding to FIG. **9**.

ST**11**: Settings at this point of time are listed. Specifically, it is assumed that the directional speed lever is in the neutral position, the electric motor drive control signal is 5% (See FIG. **9**(*b*)) and the motor drive circuits are in the free mode (See FIG. **6**B).

ST**12**: Check whether or not the directional speed lever **34** shown in FIG. **4** is in the reverse region (or in the forward region). When the answer is YES, proceed to ST**13**.

ST**13**: When the lever is in the forward or reverse region, the controller starts releasing the electromagnetic brakes **51**L and **51**R shown in FIG. **4**. The electromagnetic brakes require a certain period of time to complete the release.

ST**14**: The controller simultaneously switches the motor drive circuits to the short circuit brake mode (See FIG. **6**B).

ST**15**: Start a first timer incorporated in the controller.

ST**16**: Check whether or not time T1 counted by the first timer reaches the time t1 required to release the electromagnetic brakes. When its reaching is found, proceed to ST**17**.

ST**17**: The controller switches the motor drive circuits to the reverse mode (or to the forward mode) in accordance with the directional speed lever.

ST**18**: The controller simultaneously changes the drive control signal to the electric motors to 10% (See **P13** in FIG. **9**(*b*)).

ST**19**: Start a second timer incorporated in the controller.

ST**20**: Check whether or not time T2 counted by the second timer reaches the time t2 required to release the short circuit brakes. When the time T2 reaches the time t2, proceed to ST**21**.

ST**21**: The controller increases the drive control signal to the electric motors in accordance with the position of the directional speed lever (after **P14** in FIG. **9**(*b*)). This causes the vehicle to start traveling.

FIGS. **11**(*a*) to **11**(*e*) are time charts illustrating starting control at high-speed switching of the directional speed lever according to this embodiment, in which the horizontal axes are time axes.

In FIG. **11**(*a*), the vertical axis indicates positions of the directional speed lever, showing shifting of the directional speed lever in the forward region to the reverse region at a high speed. The directional speed lever starts moving toward the neutral region at a point **P21**, enters the neutral region at a point **P22** and moves out of the neutral region at a point **P23**.

In FIG. **11**(*b*), the vertical axis indicates a drive control signal to the electric motors, showing that high-speed shifting of the directional speed lever causes delay in signal-output reducing processing and the signal reaches 10% at a point **P24** behind **P22** and then is immediately reduced to 5%.

FIG. **11**(*c*) illustrates the operating state of the electromagnetic brakes which are switched from releasing to braking with timing corresponding to **P24** in FIG. **11**(*b*). The switching, however, takes time.

FIG. **11**(*d*) illustrates the modes of the motor drive circuits. The motor drive circuits in the forward mode are switched to the short circuit brake mode at **P24**. This processing is for complementing the releasing of the electromagnetic brakes in FIG. **11**(*c*).

FIG. **11**(*e*) illustrates traveling speed, in which the high-speed shifting of the directional speed lever causes delay in stopping the vehicle and the speed of the electric motors does not become zero until a point **P25**. **P25** is behind **P23** in FIG. **11**(*a*). At the point of time of **P25**, the motor drive circuits are switched to the free mode in FIG. **11**(*d*) and a third timer is started to wait a lapse of time t3 in FIG. **11**(*b*). The time t3 is a period of time required to switch the motor circuits from forward rotation to reverse rotation, being set at several milliseconds to dozens of milliseconds.

In FIG. **11**(*b*), the first timer is started at a point **P26** at which the time t3 has elapsed. In FIG. **11**(*c*), release of the electromagnetic brakes is simultaneously started. In FIG. **11**(*d*), the motor drive circuits are switched to the short circuit brake mode. In FIG. **11**(*b*), the second timer is started at a point **P27** at which the time t1 has elapsed and the control signal output is simultaneously increased to 10%. As shown in FIG. **11**(*d*), the motor drive circuits are switched to the reverse mode.

Further in FIG. **11**(*b*), the drive control signal is increased over 10% at a point **P28** at which the time t2 has elapsed. That is, the drive control signal is increased to a level corresponding to the position of the directional speed lever. As a result, the vehicle starts traveling rearward as shown in FIG. **11**(*e*).

FIG. **12** is a control flowchart corresponding to FIG. **11**.

ST**31**: Wait until the traveling speed Vc becomes zero. With YES, proceed to the next. This timing corresponds to **P25** in FIG. **11**(*e*).

ST**32**: Switch the motor drive circuits to the free mode. The free mode turns off all of the driving elements in the circuits, which is equal to resetting. Switching the driving elements thereafter to the reverse mode will not cause application of electrical overload to the driving elements.

ST**33**: Start the third timer incorporated in the controller.

ST**34**: Check whether or not the time T3 counted by the third timer reaches the driving element switching time t3. When the time T3 counted by the third timer reaches the driving element switching time t3, proceed to ST**35**.

ST**35**: When the time T3 counted by the third timer reaches the driving element switching time t3, releasing of the electromagnetic brakes **51**L and **51**R shown in FIG. **4** is started. The electromagnetic brakes, however, require some time to complete the releasing.

ST**36**: The motor drive circuits are switched to the short circuit brake mode (See FIG. **6**B) simultaneously with the start of release of the electromagnetic brakes **51**L and **51**R.

ST**37**: Start the first timer incorporated in the controller.

ST**38**: Determine whether or not the time T1 counted by the first timer reaches the time t1 required to release the electromagnetic brakes. When its reaching is found, proceed to ST**39**.

ST**39**: Switch the motor drive circuits to the reverse mode.

ST**40**: The drive control signal to the electric motors is changed to 10% as shown in FIG. **11**(*b*) simultaneously with the switching to the reverse mode.

ST**41**: Start the second timer incorporated in the controller.

ST**42**: Determine whether or not the time T2 counted by the second timer reaches the time t2 required to release the short circuit brakes. When its reaching is found, proceed to ST**43**.

ST**43**: The drive control signal to the electric motors is increased in accordance with the position of the directional speed lever. This causes the vehicle to start traveling.

As described above, this embodiment provides an electric vehicle of a type of controlling forward travel, neutral and reverse travel of the vehicle driven by electric motors by a single directional speed member, the electric vehicle including a controller for such control as verifying that a time period required for the directional speed member to pass through the neutral region is shorter than a threshold (ST**02** in FIG. **8**), verifying that the electric motors are still rotating in a forward direction at the point of time when the directional speed member is shifted from a neutral region to a reverse region (ST**04** in FIG. **8**), waiting until the speed of the electric motors becomes zero when the above two conditions are satisfied (ST**31** in FIG. **12**), waiting a lapse of time t3 required for forward/reverse switching of the motor drive circuits after the speed of the electric motors reaches zero (ST**34** in FIG. **12**), and thereafter shifting to normal reverse operation control (ST**35** and the following in FIG. **12**).

The electric vehicle of the present invention is not limited to the snow removal machine shown in the embodiment, and may be of any kind as long as being an electric vehicle such as an electric carrier or an electric caddie cart.

The snow removal machine in the present embodiment has left and right electric motors. An electric vehicle of this invention may be of a type having a single electric motor for driving left and right driving wheels.

The present embodiment has the single directional speed lever. Several directional speed levers may be provided to share the functions. The directional speed control member may be a lever, a dial, a switch or an equivalent.

The present disclosure relates to the subject matter of Japanese Patent Application No. 2001-355328, filed Nov. 20, 2001, the disclosure of which is incorporated herein by reference in its entirety.

What is claimed is:

1. An electric vehicle driven by electric motors, comprising:

a directional speed member for instructing forward travel, neutral and reverse travel of said vehicle and adjusting the speed of said vehicle;

said electric motors which operate in accordance with the operation of said directional speed member; and

a controller for performing such control as, when two conditions are satisfied that time required for said directional speed member to pass through a neutral region is shorter than a threshold and said electric motors are still rotating in a forward direction at a point of time when said directional speed member is shifted from said neutral region to a reverse region, waiting until the speed of said electric motors becomes zero, and, after a lapse of time required for forward/reverse switching of said motor drive circuits since the speed of said electric motors reaches zero, shifting to normal reverse operation.

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